

NASA TT F-11,670

~~WALL FLOW AND UPWARD FLOW PRODUCED BY DEFLECTION
OF FREE-STREAMS~~

Heinrich Hertel

WALL FLOWS AND FLOW IMPINGEMENTS FROM THE
DEVIATION OF FREE JET GROUPS

Translation of "Wandströmungen und Aufströme aus der
Umlenkung von Freistrahlguppen"
Fortschritt-Berichte VDI-Zeitschrift, Vol. 108, No. 19
July 1, 1966, p. 816

GPO PRICE \$ _____

CFSTI PRICE(S) \$ _____

Hard copy (HC) _____

Microfiche (MF) _____

ff 653 July 65

N 68-23519

FACILITY FORM 602

(ACCESSION NUMBER)

(THRU)

(PAGES)

(CODE)

(NASA CR OR TMX OR AD NUMBER)

(CATEGORY)



WALL FLOWS AND FLOW IMPINGEMENTS FROM THE
DEVIATION OF FREE JET GROUPS

NASA TT F-11,670

WALL FLOW AND UPWARD FLOW PRODUCED BY DEFLECTION OF
FREE-STREAMS

H. Hertel*

ABSTRACT. The lift stream of VTOL-aircraft which take off vertically and land vertically (VTOL = Vertical Take-off and Landing) is directed downward for pure vertical movement. This stream direction, as opposed to that of the usual planes, entails a number of new flow patterns. Of special importance are the "ground effects" which occur when the VTOL-aircraft is on the ground or at low altitude. To make visible propagation and interference of the wall streams on the floor and the forming of flow reservoirs, from which upward flow occurs, petroleum-black-images were made. The streams, their afflux, their effect on each other, and the upward flow from the ground were examined in vertical planes with a process using light sections. Several methods are suggested to reduce upward flow.

Flow patterns which result from the combination of free-streams which are perpendicular to the ground have been investigated in experiments in which stream propagation combined with influx and deflection were made visible, thus making it possible to determine on the ground the direction of efflux and the formation of flow reservoirs from which upward flow starts. Making flow visible enabled us to establish the pattern and the extent of upward flow. This information is valuable for making measurements of velocity distributions in the areas of upward flow and for finding methods of eliminating upward flow. /816**

The lift stream of VTOL-aircraft which take off vertically and land vertically (VTOL = Vertical Take-Off and Landing) is directed downward for pure vertical movement. This stream direction, as opposed to that of the usual planes, entails a number of new flow patterns. Of special importance are the "ground effects" which occur when the VTOL-aircraft is on the ground or at low altitude.

These ground effects are:

* Prof. Dr.-Ing. Hertel, Berlin.

** Numbers in the margin indicate pagination in the foreign text.

1. ground erosion,
2. flow encircling the airframe,
3. upward flow from the ground.

If the lifting force is produced by hot stream, then stream propagation near the ground is connected with the following thermal effects:

a) heating of the airframe,

b) "recirculation", because hot gas from the lift stream, which is mixed in with the air the propulsion unit draws in in upward flow, is sucked in again.

Sucking in heated air into the opening of the propulsion unit results in a decrease of the lifting force of the propulsion unit. Therefore, recirculation seriously threatens smooth functioning of the propulsion unit of a VTOL-aircraft near the ground. There are two causes for this upward flow which induces recirculation. First, thermal upward flow forms as a consequence of a difference in density between the hot air in the stream field and the cooler air of the environment and of the convection flow which develops out of this. Secondly, kinetic upward flow occurs as a consequence of the combined effect of several streams which, in propagating, interfere on the ground as wall streams and are therefore partly deflected upward. If several streams are present these two effects are usually superimposed.

The flow which is caused by the streams of the propulsion unit can partly be described by flow patterns in turbulent streams which have been extensively investigated. The streams of the propulsion unit first, until close to the ground, have the form of free-streams; on the ground they are deflected and propagate as "wall streams." However, until now, little is known about the interference effect of several streams on each other and on the aircraft.

Systematic investigations of this combined effect were undertaken in the Institute for Aircraft Construction of the Technische Universität, Berlin. Since, for recirculation, kinetic upward flow has to be considered more important than thermal upward flow, these experiments were conducted without heating the stream air.

To start with, the problem was reduced to very simple arrangements and only the most essential parameters. To make visible propagation and interference of the wall streams on the floor and the forming of flow reservoirs, from which upward flow occurs, petroleum-black-images were made. The streams, their afflux, their effect on each other, and the upward flow from the ground were examined in vertical planes with a process using light sections. Figure 1 shows a light sections photograph of the flow pattern in a four-stream arrangement.

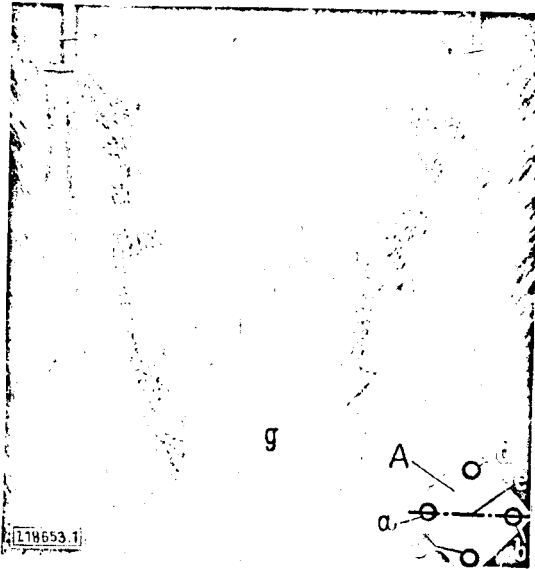


Figure 1. Stream Propagation and Upward Flow in a Diagonal Light Section of a Four-Stream Arrangement.

A: Diagram of the Arrangement

a to d: Stream Jets

e: Position of the Light Section Plane

f: Downward Streams

g: Upward Stream from the Ground

The field of the upward flow is determined by measurements at many points of the plane of stream emission. From the upward-flow fields were obtained corresponding upward-flow impulses whose values, varying with the distance from the ground, were determined for many arrangements. The investigation made use of groupings of two-, four-, and twelve-stream arrangements with varying geometrical dimensions. Many arrangements proved to be disadvantageous for "vertical engineering" because upward flow was too strong. The experiments showed that it is possible to reduce upward flow with the following methods:

1. concentrated arrangement of the lifting gear,
2. application of additional central stream,
3. attaching deflection flaps to the fuselage.

If these methods are used singly or in combination in a suitable way, upward flow can be eliminated.

Translated for the National Aeronautics and Space Administration under Contract No. NASw-1695 by Techtran Corporation, P.O. Box 729, Glen Burnie, Md. 21061

Al Hill

Per telecon with Cress Whiting, Code USS-T, the title "Wall Flows and Flow Impingements

From The Deviation of Free Jet Groups" should be used for both TT-F-11670 and
N68-22519

TT-F-11680. These reports were both authored by Heinrich Hertel. These reports ~~XX~~
X68-16340

will be announced by this title in the NASA Translations List.

Jim Watson
7/9/68